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Mobile Traffic Management System Test Deployment

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MOBILE TRAFFIC MANAGEMENT SYSTEM

TEST DEPLOYMENT

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ABSTRACT

The Mobile TMC and various field elements were developed for Caltrans Division of Research and Innovation (DRI) between 1994 and 2002. These systems were all designed to operate independent of one another to provide on-site traffic data collection, video surveillance, and traffic management functions to support Caltrans TMC operations. Cal Poly researchers integrated these systems and an off-the-shelf changeable message sign into a Mobile Transportation Management System (MTMS). This new and integrated system is capable of operation untethered from a fixed-site Transportation Management Center (TMC).

Two field tests were designed to test the field deployment capabilities of the new traffic management system. The first test utilized the new MTMS to support event management while the second test focused on supporting freeway operations. Both tests were conducted, each with different levels of technical success. The primary lesson learned from these tests regarding the operation of the Mobile TMC and deployable field elements in general is that simplicity of system setup and operation is paramount. ITS elements designed for quick field deployment must be extremely reliable, require minimal setup, and be simple to operate. Systems that do not have these attributes will frustrate operators and not meet the expectations of traffic managers.

Keywords: Mobile TMC, ATMS, Mobile Ramp Meter, Field Operational Test Trailer, Event Management, Satellite Communications, Wireless Communications

EXECUTIVE SUMMARY

The Mobile TMC was integrated with existing Caltrans traffic surveillance and mobile ramp metering trailers from the 1994-1996 Field Operational Test (FOT) in Southern California, and a changeable message sign to create a new Mobile Transportation Management System (MTMS). The Mobile TMC and the MTMS as a whole were evaluated during two field tests: event management at the annual Cal Poly Open House and ramp meter monitoring on the 55 Freeway at MacArthur Blvd in District 12.

The Mobile TMC was integrated with the field elements to leverage its traffic management capabilities as a whole. The field tests were designed and conducted to shed light on deployment issues regarding the integration of the Mobile TMC and portable field elements in general. The Cal Poly Open House event tested digital video links from modified Mobile Ramp Meter (MRM) and Field Operational Test (FOT) trailers to the Mobile TMC, collection and viewing of roadway data within the Mobile TMC, and the Mobile TMC's ability to serve as a mobile command post where traffic routing decisions were made based on traffic sensor data and surveillance video. The 55 Freeway test focused on mobile ramp metering, video collection and viewing, and relay of video and data from the field to the District 12 TMC via satellite link.

The results of both tests were positive, albeit in different ways. The Cal Poly Open House test, which went smoothly, indicated that the Mobile TMC and a Mobile Transportation Management System in general could effect a positive result in large event management. The 55 Freeway test, which had various technical difficulties, indicated that portable traffic management field elements must be reliable as well as simple to setup and operate. Both tests indicated that mobile transportation management operations are feasible, but suitable equipment coupled with sufficient planning will enhance opportunities for success in field management of transportation systems and deployment of portable field elements.

All Mobile TMC and MTMS systems should be evaluated and updated for streamlined setup and operation, providing quick-deployment capability. Less operator training would be required and the system would also be deployable with a smaller team. It is also recommended that comprehensive performance and equipment specifications be written for the Mobile TMC and the MTMS as a whole. Such a specification would facilitate procurement of new equipment for this Mobile TMS

and other portable field equipment deployments within California, and allow other districts to deploy their own Mobile Transit Management Systems.

Adding additional low-cost, quick-setup video surveillance and vehicle detection field elements to this system will provide the Mobile TMC with the ability to competently perform a variety of on-site incident management tasks currently unavailable within Caltrans. Extending the Caltrans wide area network (WAN) to perform seamless routing of compressed video among districts would leverage MTMS system extensions, allowing the Mobile TMC and its field elements to collect video from any location within California and transfer it to District 12 via the satellite link. Any video received via satellite in District 12 could then be routed via the Caltrans WAN to the district where the system was deployed.

TABLE OF CONTENTS

1. Introduction 1

2. System Modifications 2

3. Mobile Transportation Management System Field Testing 4

3.1. Cal Poly Open House Event Management 4

3.1.1. Field Test Objectives 4

3.1.2. Preplanning 7

3.1.3. Field Test 8

3.2. Highway 55 at MacArthur Blvd Freeway Ramp Meter Monitoring 10

3.2.1. Field Test Objectives 10

3.2.2. Preplanning 12

3.2.3. Field Test 12

4. Key Lessons Learned 14

5. Summary and Conclusions 16

6. Recommendations 18

1. INTRODUCTION

The primary objective of this project was to test the Mobile TMC operating with various traffic surveillance and control devices in a field environment. The Mobile TMC was integrated with two different existing Caltrans roadway surveillance and detection trailers, and a Caltrans changeable message sign (CMS). This integration required modification to one of the trailers and resulted in a new Mobile Transportation Management System (MTMS). Two field tests were designed to understand the issues associated with operation of the Mobile TMC and its associated field elements.

Cal Poly began development of a Mobile Traffic Management Center (Mobile TMC) in 1999. The Mobile TMC provides Caltrans TMC operator accessibility to field data remotely at any location within the state of California, providing traffic managers a point of presence at large incidents, special events, and natural disasters. Standard Mobile TMC functionality includes a wide-area data and video communications connection to the District 12 TMC, on-board video surveillance and vehicle detection capability, the Caltrans District 12 ATMS display, Caltrans District 12 voice radios, a worktable with whiteboard and chairs, and a kitchenette and bathroom. The Mobile TMC did not have the capability to communicate directly with any deployed field devices, rather all communications occurred via the Caltrans District 12 ATMS network.

Several existing traffic surveillance and control trailers were available to support this project. These trailers were developed by Hughes, tested in Orange County between 1994 and 1998, and are documented in the Transportation Research Board article titled "Evaluation of Mobile Surveillance and Wireless Communications Systems: Field Operational Test." Two types of trailers were developed to support this FOT: traffic surveillance and communications trailers capable of vehicle detection, video surveillance, and data communications with the District 12 TMC, and smaller mobile ramp metering (MRM) trailers.

The FOT MRM trailer used for this project was originally configured to communicate with one of the larger traffic surveillance trailers via short-range spread-spectrum radio communications. The MRM had no video surveillance or long-range data communications capabilities, and performed the sole function of ramp metering.

2. SYSTEM MODIFICATIONS

The Mobile TMC was integrated with various traffic field devices that could be deployed in the same locality as the Mobile TMC, effectively creating the Mobile Transportation Management System. Devices integrated with the Mobile TMC included one FOT Mobile Ramp Metering trailer, one FOT traffic surveillance and communications trailer, and a portable trailer-mounted changeable message sign stationed at District 12.

This MTMS functionality resulted from taking existing field elements, rather than new equipment, and making them work together. Work done to integrate each field element into the system is described below.

Mobile TMC

The Mobile TMC was used largely in its existing state to support this project. The MTMS software was written to provide for collection of remote field traffic data from both FOT trailers, and remote control of a full-matrix changeable message sign. This software provides a simple map-based graphical user interface (GUI), allowing the Mobile TMC operator to drag field detection elements and place them on a map, where the traffic data from those field elements will be displayed. Cylink spread spectrum radios and associated antennas were added to the Mobile TMC, allowing it to receive 170 controller traffic data and compressed video from the two FOT trailers.

FOT Mobile Ramp Metering (MRM) trailer modifications

Additions and enhancements to the MRM trailer included:

- short-range data communications with the Mobile TMC
- an auxiliary power generator and additional solar power generation and storage capacity
- pan-tilt control for the video surveillance camera
- an improved instrumentation platform on a taller, raisable mast

The MRM's two independent solar power systems were integrated into a single power system. The power consumption of all existing and planned MRM electrical equipment was measured and necessary solar array and battery sizes were determined. This modified power system utilized a propane powered generator as well as photovoltaic panels and batteries provided by Caltrans Division of Research and Innovation (DRI).

The existing camera and sensor mounting pole was replaced with a more substantial equipment mast, various metal fabrication was completed, and the axle and wheels were upgraded to accommodate the increased weight of the trailer. All systems were tested and the trailer was ready for operation. The modified trailer was now capable of providing traffic data and video via wireless link to the Mobile TMC, in addition to performing stand-alone mobile ramp metering.

<u>FOT traffic surveillance trailer modifications</u>

Caltrans DRI provided two FOT traffic surveillance trailers to Cal Poly for this project. The trailer's spread-spectrum modems were configured to communicate with the Mobile TMC and the trailers were made part of the MTMS.

<u>CMS & HAR</u>

A spread-spectrum data radio was integrated with the Caltrans District 12 changeable message sign and installed in a case on the sign. This radio allowed the CMS to be controlled directly from the Mobile TMC via the MTMS software previously described.

A highway advisory radio (HAR) was borrowed from Caltrans District 5 in San Luis Obispo to support the Cal Poly field test. This HAR was not modified in any way and all HAR settings were made using its existing control interface at the HAR. The HAR could not be controlled remotely.

3. MOBILE TRANSPORTATION MANAGEMENT SYSTEM FIELD TESTING

Cal Poly researchers worked with PATH and Caltrans Division of Research and Innovation personnel to select events to test deployment of the MTMC and its associated trailers and equipment. Several potential test deployments were considered for selection based upon specific factors which, including potential traffic management impact, location, deployment site traffic needs, and scheduling. Multiple deployments were desired to demonstrate the Mobile TMC's capability to operate both within the infrastructure of a TMC, as well as autonomously as a stand-alone system. An autonomous deployment would demonstrate the ability of the Mobile TMC to manage remote field elements independently of a TMC, and act as a stand-alone traffic management system.

A TMC-tethered deployment, utilizing the Mobile TMC as an extension of the District 12 TMC, was desired to demonstrate the capability of the Mobile TMC to act as a relay facility. It would not only collect video and data for local display and analysis, but also relay that information across the satellite link to the District 12 TMC.

Two field-tests were selected to test the MTMS:

- Event management at Cal Poly's annual "Poly Royal" three-day Open House.
- Freeway operations support on the 55 freeway in Caltrans District 12.

3.1. Cal Poly Open House Event Management

3.1.1. Field Test Objectives

The overall objective of this field test was to show the Mobile Traffic Management System's (MTMS) ability to be deployed to perform traffic management and surveillance tasks. This test was selected because it offered the opportunity to use various MTMS elements in a stand-alone configuration and was "close to home". Additionally, the Cal Poly Open House historically generates a dramatic excess of traffic on the Cal Poly campus and nearby roadways. The MTMS would provide event personnel with necessary traffic management information in a simplified manner, and also allow for incoming visitors to be directed effectively to available parking.

The major MTMS subsystems that would be utilized during this test include two changeable message signs, a highway advisory radio, the FOT surveillance and retrofitted MRM trailers, and the

Mobile TMC with MTMS software. The functionalities of each subsystem to be tested are explained below.

Driver Notification via CMS & HAR

Two CMS's would be deployed on Highway 101, one north of Cal Poly on southbound 101 and the other south of Cal Poly on northbound 101. These signs would notify drivers coming to Cal Poly of the correct exit. The CMSs would also notify drivers to tune their radio to the HAR broadcast frequency for further directions.

FOT Traffic Surveillance Trailer Video Transmission

The traffic surveillance trailer would be deployed between two campus parking lots and provide live video feeds of both lots over wireless link to the Mobile TMC. These video feeds would also be recorded before transmission.

FOT MRM Video Transmission

The MRM trailer would be deployed south of the main Open House entrance to Cal Poly to provide a video feed of incoming traffic over wireless link to the Mobile TMC.

Mobile TMC Command Post

The Mobile TMC would provide a central location for Cal Poly Public Safety staff to monitor current traffic and parking status and provide them with a temporary rest area.

MTMS Traffic Monitoring

The Mobile TMC would use the Cal Poly developed MTMS software to monitor traffic data through an onboard RTMS traffic sensor and associated input file and 170 controller.

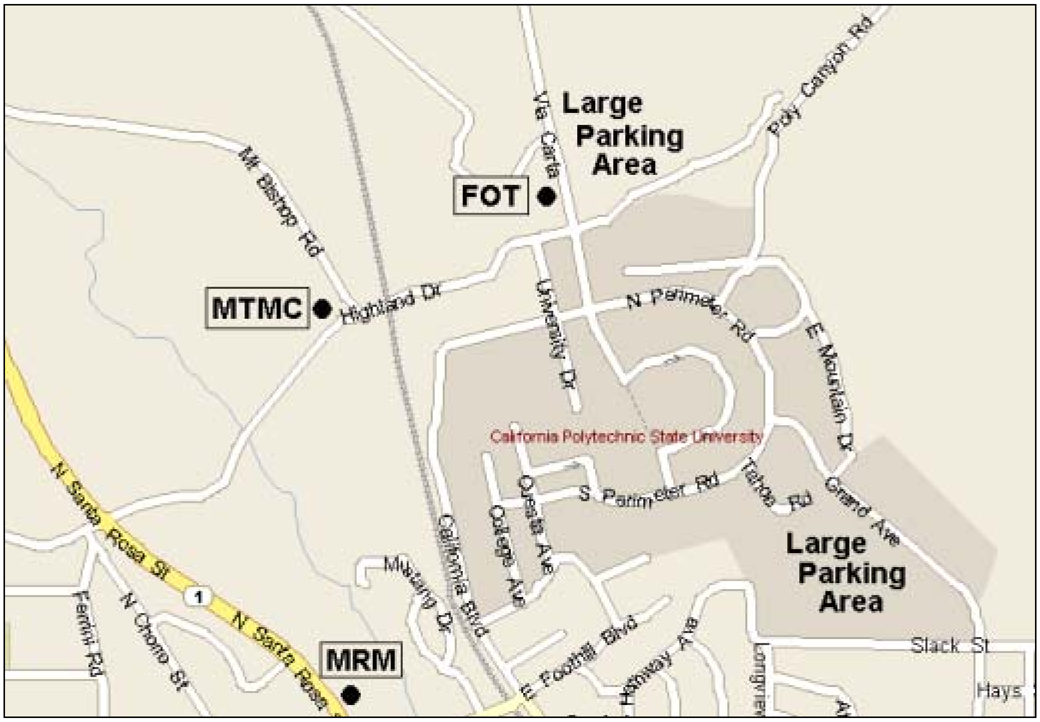

Figure 3.1 Cal Poly Open House Field Test, Campus Close-up.

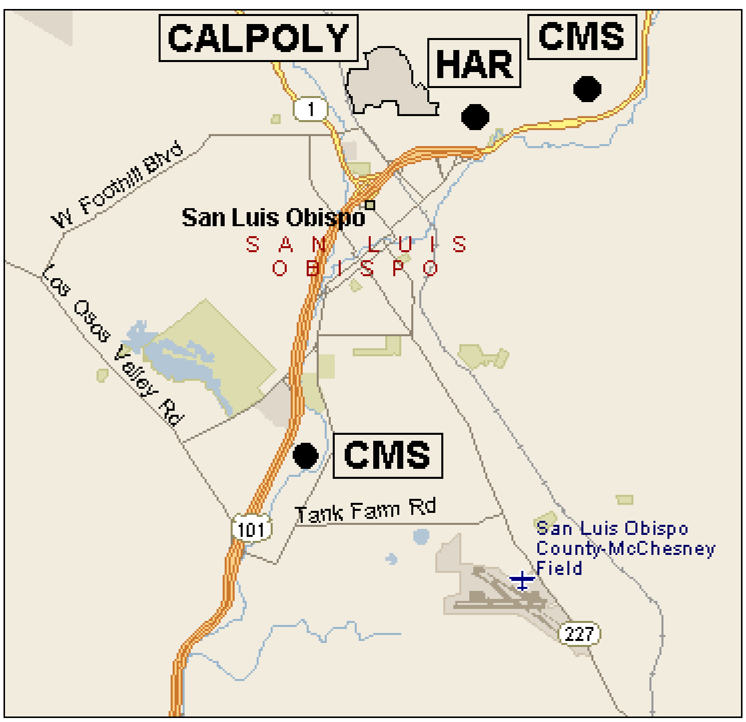

Figure 3.2 Cal Poly Open House Field Test, CMS & HAR Placement.

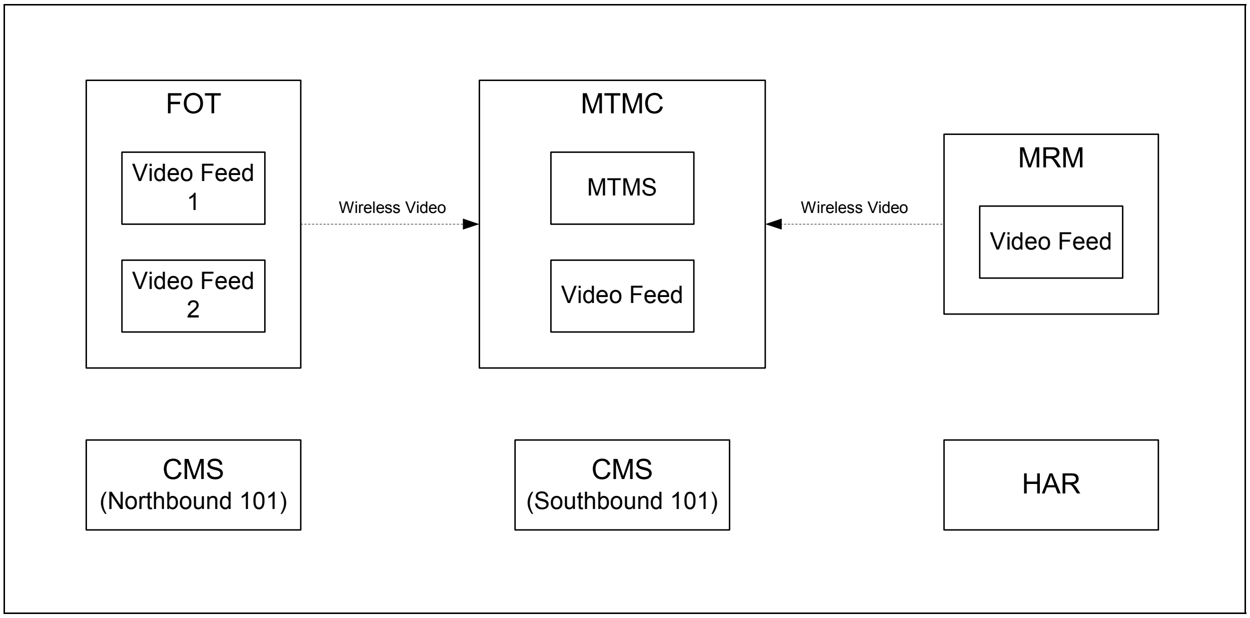

Figure 3.3 Cal Poly Open House Field Test architectural overview.

3.1.2. Preplanning

Preplanning began by meeting with Cal Poly Police to discuss the project and how its goals might fit those of the managing the upcoming Open House. The research team then attended Open House planning meetings to better understand the traffic management requirements. The team simultaneously met with local Caltrans staff to arrange the loan of a CMS and a HAR to Cal Poly for the event. Cal Poly also met with local CHP staff to understand their needs.

The next step in preparation for the Open House was a careful review of traffic management needs, and potential deployment sites for the Mobile TMC and the five trailers. Trailer and Mobile TMC deployment site selection was dependent on both traffic and parking lot observation needs, desirable locations for the Mobile TMC from a command post perspective, line-of-site communications limitations, a good A.M. radio frequency transmission location for the HAR, and CMS locations which would give travelers an opportunity to tune to the HAR station for advisory information. The San Luis Obispo area is hilly with many tall trees, so careful planning of the 256Kbps data radio links was critical. Once Cal Poly researchers came up with a deployment plan, Public Safety was consulted for a final review.

3.1.3. Field Test

CMS & HAR Driver Notification

Messages posted on the north and southbound 101 CMSs and the HAR were effectively used to notify drivers of current traffic and parking conditions. Drivers who were not familiar to the San Luis Obispo area were given needed information to direct their travel to Cal Poly. Midway through the test, University Police decided to redirect traffic to parking lots on the North side of campus. This was done as parking lots on the south end of campus, near the event, were reaching capacity. Cal Poly researchers updated the HAR and CMS messages and an adverse parking condition was successfully avoided.

Although all objectives were completed, minor issues were experienced during testing. Each CMS was designed to be controlled via cellular link. Due to the nature of CMS acquisition, Cal Poly researchers were not able to take advantage of this feature. The spread-spectrum link to the CMS implemented by Cal Poly would not work across San Luis Obispo due to terrain issues, so CMS updates had to be applied manually, which delayed information reaching incoming drivers. The HAR is also designed to be controlled wirelessly, and this too was not available. In addition, the HAR did not have enough power to function throughout the entire test and was inoperable during the third day of the test.

FOT Video Relay

The FOT successfully transmitted a live video feed from its remote location to the Mobile TMC over a wireless link. This allowed University Police to easily monitor the status of two parking lots used for event parking. The video feed was relatively uninterrupted throughout the entire test and reliably provided assistance to law enforcement personnel. Short interruptions in wireless communication were experienced between the Mobile TMC and FOT, due to the issues with the directional antennas. As mentioned previously in CMS & HAR Driver Notification, information gathered from this relay provided Cal Poly police with the ability to redirect traffic and avoid motorists entering an area of campus where parking was unavailable. The FOT was also able to record its video feeds for additional analysis of traffic and parking patterns.

MRM Video Relay. The MRM successfully transmitted a video feed of the primary Cal Poly Open House entrance at the intersection of Highland Drive and Highway 1. This allowed University

Police to monitor the current traffic flow and identify vehicles driving illegally onto campus. Due to the natural terrain of this location, obtaining line of sight through tall foliage between the Mobile TMC and MRM was difficult. This resulted in variable video reception. Cal Poly researchers were able to re-aim the antennas periodically to mitigate this problem.

<u>Mobile TMC Command Post.</u> The Mobile TMC was located in a position that was easily accessible to University Police officers. Throughout the event, the Mobile TMC served as a command station and rest area for law enforcement personnel. These individuals were able to enjoy the simple amenities provided by the Mobile TMC and easily monitor the current traffic and parking status. The Mobile TMC also provided an additional video feed from its onboard mast-top surveillance camera that could be used to monitor nearby traffic conditions and event proceedings.

<u>MTMS Traffic Monitoring.</u> The Cal Poly developed MTMS was used successfully to retrieve data from an RTMS traffic sensor located on the Mobile TMC. Cal Poly researchers were able to monitor traffic flow on one lane of traffic from the Mobile TMC operator console.

3.2. Highway 55 at MacArthur Blvd Freeway Ramp Meter Monitoring

3.2.1. Field Test Objectives

The primary objective of this field test was to show the MTMS' ability to integrate with Caltrans traffic management infrastructure. The MTMS would be deployed to act as a remote video and data source that would be transmitted via satellite to the Caltrans District 12 TMC. The Mobile TMC would also act as a remote terminal to view the District 12 ATMS. In addition, the Mobile TMC would collect traffic data for the 55 Freeway and McArthur Blvd. onramp. This location was chosen for its ease of access due to Caltrans construction at the overpass, and relatively close proximity to the District 12 TMC.

The major subsystems that would be utilized during the test included a FOT surveillance trailer, the Cal Poly retrofitted FOT ramp metering trailer, wireless video links, and the Mobile TMC with satellite link and MTMS software. The functionalities of each subsystem to be tested are explained below.

<u>FOT Surveillance Video Relay</u>

The traffic surveillance trailer would be located beside the McArthur Blvd. onramp to the 55 Freeway south. It would transmit a video feed via wireless link to the Mobile TMC. This video feed would alternately show traffic on the 55 both downstream and across from the onramp. This video feed would also be recorded for later review.

<u>Mobile Ramp Meter Video and Data Relay</u>

The MRM would be deployed near the end of the McArthur Blvd. onramp. A live video feed of onramp traffic would be wirelessly transmitted to the Mobile TMC. In addition, traffic data for the 55 Freeway would be collected by an RTMS and also be transmitted to the Mobile TMC.

<u>MRM Ramp Metering</u>

The ramp-metering pole would be set up and configured to meter ramp traffic, but in a test capacity only. This would non-intrusively test ramp meter operation.

MRM Solar Power System

The MRM had been retrofitted with a solar power system so that it could operate solely on battery power. This test would prove its effectiveness.

Mobile TMC Video and Data Monitoring

The Mobile TMC would display all video feeds from the MRM and FOT. Data from the Mobile Ramp Meter would be monitored on the Mobile TMC by the MTMS. In addition to this remote data, the MTMS would also monitor traffic data on an onramp near the Mobile TMC collected by an onboard RTMS.

Mobile TMC Satellite Communications

Two-way communication would be established over the VSAT satellite link between the Mobile TMC and District 12 TMC. The TMC Front End Processor (FEP) would be able to poll the Mobile TMC's 170 controller for traffic data across the satellite link. The District 12 TMC would forward an ATMS display across the satellite link, allowing the Mobile TMC to display the current ATMS. In return, the Mobile TMC would transmit one video signal for display on the District 12. Finally, video conferencing capabilities would be tested across the satellite link.

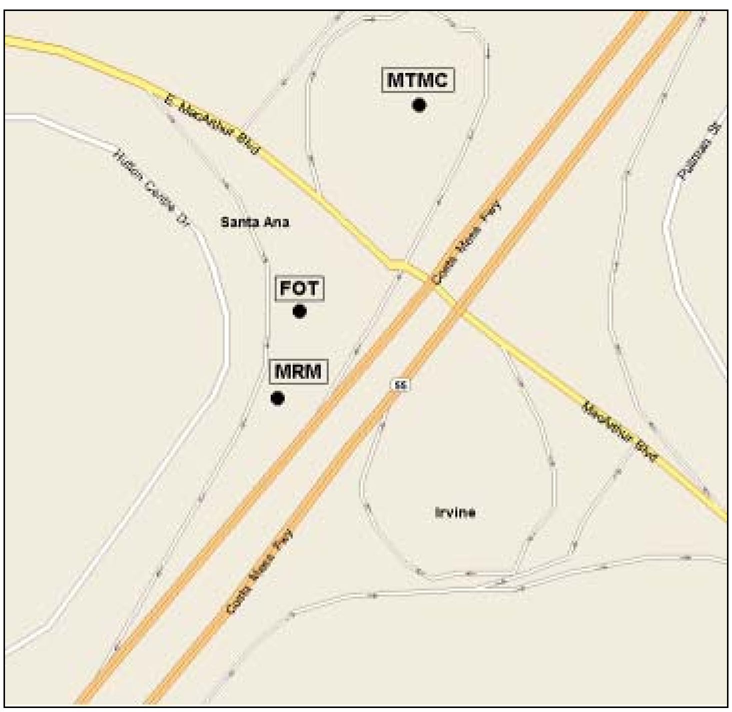

Figure 3.4 Field Test at the 55 Freeway.

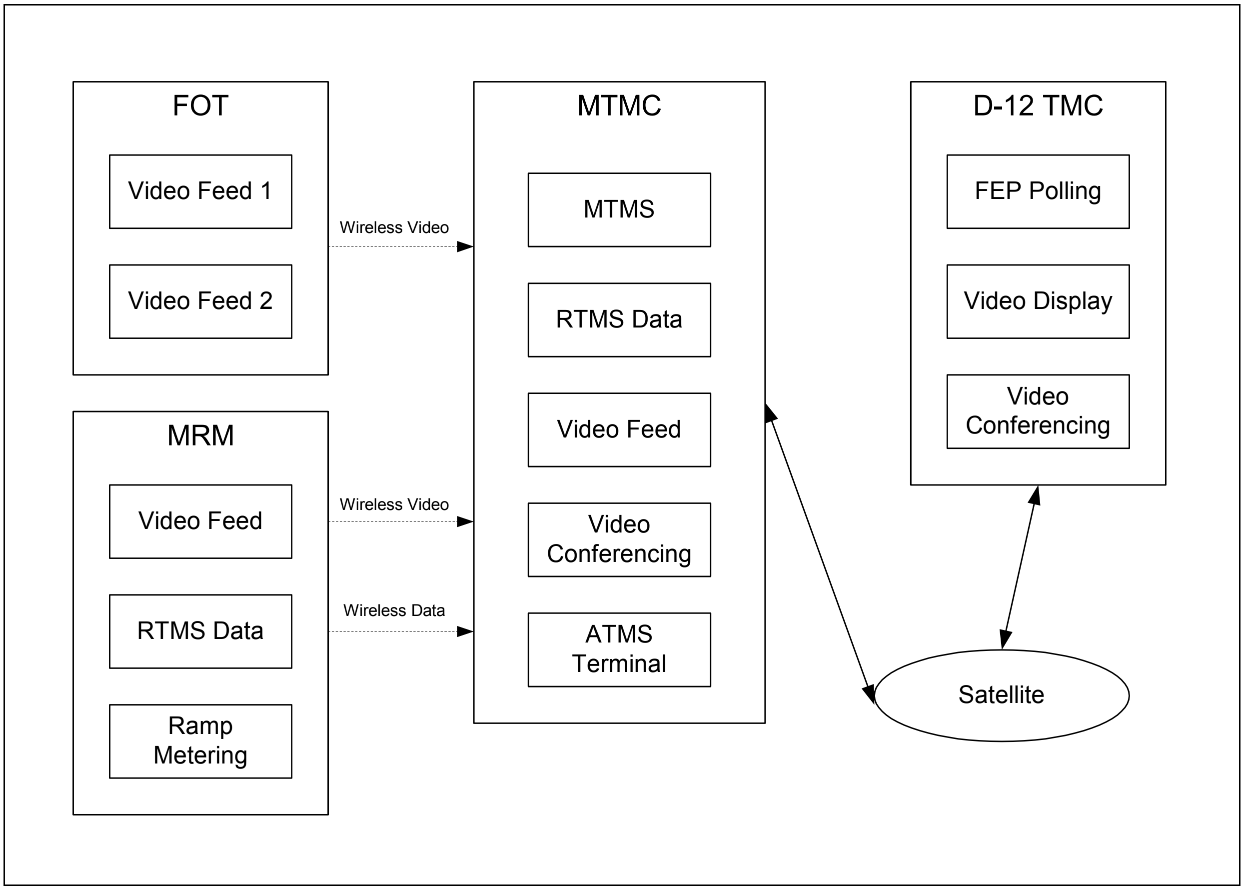

Figure 3.5 55 Freeway Field Test architectural overview.

3.2.2. Preplanning

The 55 Freeway test was preceded by minimal preplanning. Caltrans District 12 technical staff selected the location for the Mobile TMC and both FOT trailers. Cal Poly performed a quick inspection of the test site and determined that it posed no communications link issues.

3.2.3. Field Test

<u>FOT Surveillance Video Relay</u>

The trailer successfully transmitted its video feed across the wireless link to the Mobile TMC. This feed was also recorded onboard the surveillance trailer throughout the test. In addition to local display of the feed aboard the Mobile TMC, it was also relayed back to the TMC for display. As experienced in the Cal Poly Open House test, directional antenna aiming issues surfaced. Weather played a factor in aiming the antennas and was a major hindrance to ensuring consistent video transmission throughout the entire test. It was also determined that the pan tilt units, which originally had directional antennas on them on the FOT trailers, were not sturdy enough for the load of the antennas.

MRM Video and Data Relay

The MRM successfully transmitted its video feed of traffic on the McArthur onramp. Again, communication between directional antennas was an issue. The RTMS was configured and seen to work local to the MRM, but data was not successfully transmitted wirelessly to the Mobile TMC. This was most likely due to a communications configuration issue between the MRM and Mobile TMC, not due to an issue with the RTMS.

MRM Ramp Metering. The ramp-metering pole was successfully set up alongside the ramp and connected to the MRM's 170 controller. The demand and passage sensors were attached to the side of the MRM and to the 170 controller. All of these devices performed as expected.

MRM Solar Power System. The MRM successfully ran on solar power without any glitches. An extensive test of solar power system autonomy was not completed due to the time constraints of the field test.

Mobile TMC Video and Data Monitoring. The Mobile TMC was able to successfully receive video from both the ramp meter and video surveillance trailers. These video feeds were displayed to operators, along with its own surveillance camera provided. As explained in MRM Video and Data Relay, data was not successfully received from the MRM. However, the MTMS was able to monitor traffic data from the RTMS sensor on the Mobile TMC. Data for the 55 Freeway was collected during this test.

Mobile TMC Satellite Communications. Satellite communication was established between the Mobile TMC and TMC. The ATMS was successfully transmitted to the Mobile TMC for remote usage. In addition, a live video feeds from both the surveillance and ramp meter trailers were successfully transmitted and displayed on the TMC floor. Video conferencing was also established across the satellite link. However, the District 12 Front End Processor (FEP) was never able to successfully poll across the satellite link due to configuration issues. Satellite communication experienced an inopportune loss of signal and hence service due to inclement weather.

4. KEY LESSONS LEARNED

Preplanning will help yield a successful event, but be prepared to spend time doing it.

Considerable effort went into understanding allied agency needs, evaluating equipment placement feasibility, and developing a successful deployment plan for the Cal Poly Open House. The radio communications systems would not have worked had the line-of-site links in San Luis Obispo's hilly and tree-lined terrain not been well planned in advance.

Directional antennas pose difficulties in a temporary deployment.

High-speed data modems benefit from directional antennas such as yagis, but require careful setup and can come out of proper alignment easily in a temporary installation. Omni-directional antennas are a preferred choice unless extended transmission distance required. If directional antennas are required for extended distance or high bit-rates, ensure that a sturdy aiming device with sufficient angular resolution is utilized, helping to alleviate link-loss problems.

The Mobile TMC/MTMS may have more uses than typical incident management tasks.

Evaluation may yield unexpected system uses. Remote video surveillance capability was primarily intended for direct surveillance of roadways, but it also worked very well for parking management in the Cal Poly test. Remote observation of parking lot utilization allowed Cal Poly Police to redirect traffic as various lots reached capacity.

Installed auxiliary air-conditioners are insufficient to cool the Mobile TMC with several occupants.

High temperatures during the Cal Poly Open House required use of on-board climate control to maintain a comfortable working environment for both the researchers and various allied agencies utilizing the Mobile TMC. The auxiliary systems were added to the vehicle to remove the need to run the vehicle's engine to cool the cabin, but proved to be unable to sufficiently lower, or even maintain the temperature at comfortable levels without the assistance of the vehicle's primary air conditioning system. The vehicle's primary HVAC systems were observed to be quite capable to the task, and vehicle's engine did not prove to be a distraction to operators as previously hypothesized. A more effective roof-mount auxiliary air conditioning system, similar to what is used on motor homes, might be a good choice for the Mobile TMC as it would provide cooling under generator power, allowing the vehicle engine to be left off except during transport.

Complicated system setup can slow down deployment. Systems should be designed for simple use to aide rapid deployment.

Streamlining operation and reducing both setup time and personnel required for a system's operation should be a primary consideration during design and integration. Several key Mobile TMC systems would greatly benefit from modifications to simplify startup operations. Aiming of the Mobile TMC's 1.2-meter antenna is time consuming and requires multiple personnel to aim properly. Even with proper aiming, minor inaccuracies can cause communications issues, especially during inclement weather. Directional spread-spectrum data and video communications between the Mobile TMC and its associated field elements require multiple personnel working together to establish the links, and could benefit from omni-directional antennae which would eliminate the aiming requirement on these links.

Stand-alone components yield higher quality, more reliable operation.

The original Mobile TMC design utilized software-based video decoding. This system proved to be unreliable due to ease of misconfiguration of the PC it was installed on. Although PC based computer systems are extensible, configurable, and low cost, their lack of reliability makes them a false economy when installed in a system such as the Mobile TMC.

5. SUMMARY AND CONCLUSIONS

The integration of existing field elements into a functional MTMS was a success. This MTMS was demonstrated to provide operational benefits when utilized to support event management at the Cal Poly Open House. The Cal Poly Open House utilized many of the Mobile TMC's intended features, including video surveillance, changeable message sign control, and serving as a field outpost for traffic management staff. The Cal Poly Open House also provided the ability to use this system for parking management, a function that had not been directly considered previously. The MTMS ended up working for this purpose due to the flexible nature of the remote field devices: although the FOT surveillance and communications trailer is capable of vehicle detection and reporting, only its video surveillance capabilities were utilized.

The Mobile TMC and its two trailers also demonstrated that it had the technical capabilities to support freeway management operations. This system was able to successfully relay video from either of its trailers to the District 12 TMC, demonstrate mobile ramp metering functions, and provide a command post for field personnel.

The two field tests utilized different features and capabilities of the MTMS, and hence provided different results. The Cal Poly Open House test went more smoothly, demonstrating that the various technologies could work together to provide a valuable service. The Cal Poly test was preceded by extensive pre-event planning, communications link testing, and equipment set up. Also, all members of the team that integrated the MTMS supported the Cal Poly Open House event. This significant amount of preparation and support undoubtedly contributed to the positive results. The 55 Freeway test was planned to be conducted on a much more ad-hoc basis. The MTMS elements, which had all been previously tested, were placed on site and brought on line. This test brought to light various technical problems, ranging from satellite communications rain fade which interrupted ATMS operation in the Mobile TMC and video transmission to the District 12 TMC and difficulty with the wireless video links to the Mobile TMC from the trailers.

The technical successes and failures of these two tests point to a key conclusion: Any MTMS subsystem that requires more than simple procedures to set up and operate will greatly jeopardize the functionality of the entire system. Most technical difficulties and failures in these tests were rooted in subsystems that required detailed and careful setup or had too many configuration options. Either of these attributes greatly increases the likelihood of a subsystem becoming inoperable.

At first glance, one might observe that if the system operators were more careful with setup, these problems could be avoided. The technical success of the Cal Poly Open House test demonstrated that careful system setup can mitigate technical difficulties. The 55 Freeway test was conducted by many of the same people, but in a method much more similar to how the MTMS would be deployed in an operational freeway management environment: tow it from the Caltrans yard to the deployment site, turn it on, and start using it. This realistic mode of use makes it imperative that all subsystems are as simple as possible. Field utilization of a system such as the MTMS presents many inherent challenges aside from technological complexity, including extreme temperatures, inclement weather, dangerous traffic close by, and working in the dark. MTMS systems and their operation must be as fault tolerant as possible. Dedicated hardware to perform system functions such as video compression and decompression should be utilized when possible. Wireless radio communications systems must have simple or no antenna aiming procedures. More complicated systems such as the satellite communications link should have their complexity reduced through features such as an antenna that deploys and aims with minimal human input.

Aside from reducing the technical complexity of a system, other setup processes should be made as simple as possible. Rather than requiring the operator to climb on the roof to assist in deployment of the pneumatic instrumentation mast, the mast should be able to be deployed from within the vehicle. All features should be specified and implemented to minimize steps taken by the operator or exposure of the operator to dangerous conditions such as being on the vehicle roof or being near traffic. All systems and subsystems should aid in quick, easy, and reliable system deployment. This will increase system effectiveness and hence maximize Caltrans congestion reduction efforts.

In closing, one additional conclusion has been made: the MTMS has the ability to indirectly improve incident management processes and future goals at allied agencies through a first-hand demonstration of ITS at work. The MTMS was deployed for a one-time event at the Cal Poly Open House. It provided management within Cal Poly Public Safety with new perspectives on how various technologies can improve their ability manage an event. Cal Poly Public Safety requested the MTMS the following year based on their success during this field test.

6. RECOMMENDATIONS

The Mobile TMC should be modified to improve its ease of use by replacing the manually aimed satellite dish with a unit capable of auto deployment and aiming. Although the satellite communications link has other complexities associated with operating it, no better alternative capable of providing a quality data connection from virtually any location in California exists, and hence this system should remain part of the Mobile TMC. The pneumatic mast should be configured to allow deployment without personnel needing to be on the roof, improving safety and reducing setup time. The auxiliary air conditioner on the Mobile TMC should be removed because it is ineffective and takes up valuable space. A more suitable auxiliary air conditioning system should be added to the Mobile TMC. The directional yagi antennas on the Mobile TMC and the FOT trailers should be replaced with omni-directional antennas to simplify system setup. The Mobile TMC to District 12 video compression and decompression equipment should be replaced with a dedicated hardware-based video CODEC solution. All Mobile TMC/MTMS systems should be evaluated to determine if they are candidates for replacement with systems that require less setup.

A comprehensive performance and equipment specification should be written for the Mobile TMC and the MTMS as a whole. Such a specification would facilitate procurement of new equipment for this Mobile TMS and other portable field equipment deployments within California, and allow other districts to develop their own Mobile Transit Management Systems.

Cost-effective quick-setup video/vehicle detection pods should be sought after for inclusion into the MTMS, providing the system with the capability to provide rapid deployment video surveillance capabilities. The MTMS's capability to perform video surveillance and relay the video to a central site such as the District 12 TMC is a useful feature which could likely be utilized in a variety of special-circumstance situations, including wildfires, natural disasters, and terrorist attacks. The Caltrans wide area network (WAN) should be upgraded with video compression and decompression equipment to allow easy video transfer between districts, facilitating the transport and sharing of MTMS video between districts.

The Mobile TMC should be upgraded to be able to receive, display, and relay more video links. This would allow the Mobile TMC to provide the valuable function of acting as a video relay station from the field to Caltrans District 12, where the video could then be transferred to other districts via an upgraded Caltrans WAN. The Mobile TMC's existing satellite communications system can reconfigured to support transfer of several compressed video links.